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ring series of impacts, of the smaller nebula. So far as we can now see, the most serious difficulty in framing a consistent hypothesis along this line lies in the approximate circularity of the present planetary orbits, but as circularity may result from the combination of a large number of constituents having elliptical orbits, this difficulty may not prove insuperable.

We naturally turn to the heavens for nebulae whose evolution might give a system of low mass and high momentum in the outer part and high mass and low momentum in the central part. The spiral nebulae offer the greatest promise of conforming to these demands for they seem to present attenuated outer matter irregularly dispersed and perhaps in relatively high motion, while the central portions are usually denser and seem to possess less momentum relatively, but this is little more than pure conjecture based on their forms, for nothing is positively known of the dynamics of these masses. Professor Keeler has shown by recent photographic researches that spiral nebulae are the dominant forms among the smaller class. This justifies us in giving them precedence in attempts to find analogies for the origin of our system. This suggestion may really be identical with the preceding, for, in the absence of any knowledge of the origin of spiral nebulae, it is possible to conjecture that they arose from peripheral collisions of antecedent nebulae.

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July 9, 1900.

THE ILLUSORY DUST DRIFT. A CURIOUS
OPTICAL PHENOMENON.

It is of course improbable in the highest degree that the phenomenon here to be described has entirely escaped notice hitherto, but the writer at least is unaware of any existing description of the same. The

conditions under which the illusion arises are so easy to fulfill, and the resulting appearance is so odd in many ways, that the readers of SCIENCE may be interested in a brief description of the matter. The only 'apparatus' required is a set of black and white lines and a dark background near by. The best results, perhaps, are obtained by using a square yard of common black cloth bearing narrow white lines not more than two millimeters apart. Such cloth may be obtained at any large dry goods store. If now this be hung upon the wall in a strong light, and a square of dull black cardboard be placed above it, or at the side, everything is ready for the observation. Picking out some point near the center of the cloth, let this be fixated steadily for not less than twenty seconds. Then transfer the gaze quickly to the black cardboard, and the illusory dust drift will appear. The appearance is that of *a thin cloud of fine white dust moving across the field of vision*. Or the tiny particles seen may be likened to the motes in a sunbeam, since they much resemble these in density. A steady fixation of the eyes is at no time absolutely essential. They may roam freely over the cloth and then later over the dark background, though the illusion under these circumstances is diminished in strength. The best results are unquestionably secured by as resolute a fixation of the cloth as possible. The necessary *duration of this fixation* seems to depend upon the retinal sensitiveness of the observer. Probably 5 sec. is the minimum for any noticeable after effects, while no advantage seems to be gained in any direction by prolonging the fixation beyond a period of 30 sec. In practice, successive renewals of the illusion may be accomplished by very brief fixations, provided only that the time of the first fixation be moderately long.

The *duration of the illusion* seems also to be an individual matter. One observer can

still see traces of the 'dust' after a lapse of 30 sec., while in another case everything had disappeared at the end of 4 sec. Perhaps 10 sec. would be a fair average duration. At about this time the regular after-image is apt to make its appearance, and this tends strongly to drive the illusion away.

But the really interesting point in the matter is the *direction* of the moving drift. This turns out to be directly dependent upon the direction of the lines in the field of fixation. The most general statement of the matter is that, however these lines may lie, the illusory dust currents run in a direction *perpendicular* to them. Quite often, however, it is impossible to speak of the direction as strictly perpendicular, since the course of the drift may be along curved lines, as if a tiny whirlwind had caught up a bit of light, fluffy snow. Or, further—and this is perhaps most often the case—there are secondary currents visible whose directions do not coincide with that of the main stream. Nevertheless some particular direction is almost invariably more prominent than any other, and the statements of various observers show that the direction of the most vivid stream is most decidedly perpendicular to that of the lines. If the lines are vertical, the drift is usually to the *left*, though some subjects see it always to the right. If the lines are horizontal, the tendency to see the drift running *downwards* seems to be slightly more marked. Nearly as many subjects, however, see an upward drift, and quite often currents are seen to run side by side in *both* directions.

If the experiment be so arranged that half the field of fixation is occupied by vertical and the other half by horizontal lines, two clearly separated currents will appear in the illusion with horizontal and vertical directions respectively. Or if the usual field of fixation be divided by a vertical strip of some uniform color, no 'drift' will be seen

in that portion of the field corresponding to the strip. If the centre of a set of concentric black circles upon a white ground be fixated, the resulting illusion suggests a confused boiling movement, sometimes running in converging lines towards the center, sometimes passing in diverging lines towards the periphery of the field.

Now the oddity of this illusion consists precisely in this: that without intentional movement either of eyes or of object, there is yet an after-effect in the form of a definite and unmistakable perception of motion. An ordinary after-image of motion requires a previous objective movement of some sort. Here, on the other hand, we can only say that the resulting perception is *as if* there had been a previous and actually perceived motion. And this latter is exactly the case with another peculiarity not directly connected with the illusion itself. After steadily viewing the cloth for say 30 sec., the closely set lines begin to appear beaded. They are no longer straight, but wavy. And even the after-image when it appears presents the same aspect. Now this result is identical with that produced by actual movement of parallel lines across the retina.* Accordingly we have in connection with this illusion, two phenomena that ordinarily follow actual movement. This fact would seem to indicate the direction in which an explanation is to be sought. For while there is no intended movement of the eyes during the fixation of the cloth, there are certainly *impulses* to movement aroused by the various lines about the fixation-point. Every one knows how hard it is to let the eyes come to rest in a field occupied by such lines. Each one of the latter solicits the center of fixation to rest upon it. The impulses to movement are then in directions perpendicular to the lines,

*This has been well described by von Fleischl, Sitzungsber. d. Wiener Acad. 1882, Bd. 86, III. Abth. S. 8.

in other words, in the same directions as the currents of the illusory dust-drift. And, taking all into account, it cannot be very far out of the way to conjecture that the same fundamental factors are at work here as in the familiar cases of the artificial waterfall and the rotating spiral. Mere impulses to movement have taken the place of actual movements in the production of after-effects.

An attempt to obtain the illusion with *monocular* vision is attended with quite surprising results. For even after a full minute's fixation of the cloth, *no 'drift' is to be seen on the black background.* And the result is the same whether both eyes, or the one eye only, be open at the moment of transferring the gaze to the black surface. There is instead an interesting set of phenomena which do not appear in the binocular experiments. Now the illusory dust-masses come to view *during* the fixation. They are not wholly like those above described, but present rather the appearance of fine meshes formed of light gray cobwebby lines. Sometimes these meshes appear to lie slightly in front of the cloth, and if the effort is made to fixate them they temporarily disappear. Movements are by no means wanting, but there is an intermittence about them which the binocular phenomena never show. A closer examination of this net-work character of the illusion reveals the fact that each eye, the closed as well as the open, is contributing to the total effect. This may be readily demonstrated as follows. Let either eye, the *left* for example, be entirely screened from the cloth by a tiny box, or something similar, blackened within, the eye remaining open and free to move. Let the *right* eye fixate the lines. Now while this right eye remains open, the most prominent illusory movements are decidedly those running *perpendicular* to the direction of the lines. This is true no matter how the lines may lie in the field of vision. But if this

right eye be closed after a brief fixation, another set of movements is seen projected into the dark field of the covered *left* eye. These movements, though possessing neither vigor nor great vividness, are invariably in the *same* direction as the objective lines. That which moves here is less a dust-cloud than a set of fleecy or worsted-like bands, in the midst of which the 'crossed' after-image of the lines of the cloth soon appears. In addition then to the regular transference of an after-image to the field of the unstimulated eye, we have here the transference also of an illusory after-effect. The illusion is to be sure not wholly the same for the two eyes, but neither are crossed after-images entirely identical in character with the direct after-images. The interesting features then of the monocular experiments are that the illusion appears for the stimulated eye during the period of fixation only, and that the unstimulated eye also presents illusory effects of the same general character as those experienced by the open eye.

It can hardly be said with full certainty that these monocular phenomena have contributed anything decisive towards the explanation of the binocular form of the illusion. Nevertheless there is a point of difference between the two forms which cannot be wholly without meaning. There is, namely, in the monocular experiments a relative absence of the feeling of unrest during the period of fixation. The single eye seems to fixate the chosen point with far less effort. Solicitations to its movement are noticeably absent, and the time of stimulation can be prolonged without discomfort to a point where the binocular stimulation would have become exceedingly disagreeable. Now whether this absence of vivid impulses to movement may be regarded as alone responsible for the difference in the illusion can of course not be affirmed with complete confidence. But it seems

probable on the whole that the ultimate explanation of this, as of all after-images of motion, will be somehow formulated in terms of impulses to movement aroused by the particular stimulation that precedes. Perhaps the experiments here recorded may contribute their mite towards this final explanation, if that ever comes.

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RAFINESQUE'S *WESTERN MINERVA*, OR
AMERICAN ANNALS OF KNOWLEDGE
 AND LITERATURE.

It has been the writer's good fortune to discover in the library of the Academy of Natural Sciences of Philadelphia a copy of Rafinesque's *Western Minerva, or American Annals of Knowledge and Literature*, of which the only information possessed had been taken from the prospectus published as an advertisement in the *Kentucky Reporter* of 1820. The great rarity of the work is explained by its author in his 'A Life of Travel' (1836), page 66, as follows: "Ever since 1821 I had proposed to publish a literary and learned journal, the *Western Minerva*; subscribers were procured, the printer had also made a contract with me, and the first number was printed; when he dared to suppress it, at the request of some secret foes of mine, who probably paid him for it. I only saved three copies of it * * *."

The copy now under observation is a small quarto, with a page measurement of 113x183 millimeters (exclusive of margins). The matter is printed in two columns to the page, and consists of vi + 82 pages, of which the preface and dedication are not double-columned, and pages 81-88 are without doubt original proof sheets, as they are printed on one side only, and bear corrections in ink of typographical and other errors, with such notes as "I must see another proof," etc.

Aside from the rarity of the work, it contains several articles of extreme interest to naturalists, as new names for plants are proposed which have not as yet been noted in synonymy, or else have not been given such an early date in scientific nomenclature. In bringing these matters to the attention of those interested it has seemed advisable to describe the work from the beginning, referring to the non-scientific articles, or the apparently least interesting of these, by title only.

Western Minerva, | or | *American Annals* |
 of *Knowledge and Literature*, | Un peu de
 tout, | Food for the Mind, | first volume, |
 for 1821, | Lexington, Kentucky. | Pub-
 lished for the editors, by Thomas Smith,
 in quarterly num- | bers, four of which
 form a volume, at \$2 per annum. | 1821.

Page ii. Blank.

Page iii. Dedication, "To the Trustees, President, Professors and Tutors of Transylvania University * * *."

Page iv. Blank.

Pages v, vi. Preface [Dated Lexington, January, 1821].

Page 7. Headed with the title as on title-page to the word literature, with the addition of the following: Containing original essays upon Science, the Arts, Literature, and subjects connected with the Civil and Natural history of the Western States. Vol. I. Lexington (Ky.), January, 1820. No. 1.

Pages 7-11. Under the heading Legislation, is Principles of Political Wisdom, * * * Translated from the Greek by Benjamin Franklin.

Pages 11-18. Ethics, or Moral Philosophy. The Moral Decameron * * * Translated from the Greek * * * by Benjamin Franklin.

Pages 18-22. Metaphysics. Theory of the Creation or Emanation of Beings, etc. [Signed, Leibnitz and dated Lexington, October, 1820].